7th Int. Symp. "Nanostructures: Physics and Technology"
St Petersburg, Russia, June 14–18, 1999

Dressed polariton emission in III–V semiconductor doped with quantum wells or quantum dots

M. Singh, W. Lau and J. Desforges
Department of Physics, University of Western Ontario, London, Canada

The most interesting phenomena in photonic band gap materials are the formation of photon-atom bound states and suppression of spontaneous emission from the photon-atom bound state [1]. Recently, Rupasov and Singh have studied the quantum electrodynamics of a two-level atom placed within a frequency dispersive medium whose polariton spectrum contains a energy gap [2]. They found that if the atomic resonance frequency lies within the gap, then the spectrum of the system contains a polariton-atom bound state with an eigenfrequency lying within the gap. The radiation and medium polarization of the bound state are localized in the vicinity of the atom. In photonic band gap materials, the existence of the photonic band gap is due to multiple photon scattering by spatially correlated scatters, while in dispersive media such as semiconductors and dielectrics, the energy gap is caused by photon coupling to an elementary excitation (excitons, optical phonons etc.) of the media.

The aim of the present paper is to study the dressed polalriton emission in III–V semiconductors doped with two-level quantum wells or dots. Making use of the spherical harmonic representation and the dipole resonance approximation, we derive an effective model Hamiltonian of the system, which, in the limiting case of empty space, coincides with the model Hamiltonian obtained in liturature. To find the self energy function of the system we diagonalize exactly the Hamiltonian in the one-polariton sector of the entire Hilbert space. To study the spontaneous decay rate of an initially excited dressed state of the polariton system, we consider that the resonance frequencies of a quantum dot lies either inside or outside the polariton gap. We obtain for the first time the dynamic Stark effect due to polariton dressed states. This effect is very similar to that of photon-atom dressed states in quantum optics. We also study the spontaneous decay rate of a system doped with two quantum dots. We consider the case in which one quantum dot is in the excited state while the other is in the ground state with no polaritons present in the system and the resonance frequencies of two dots lie in the polariton continuous spectra. It is found that when the distance between the two dots becomes very large, the spontaneous decay rate of the excited state is equal to that of the single dot case. For very small distances, it is found that the rate of spontaneous emission from the symmetric state is two times that of the single dot case. This phenomenon in quantum optics is called superradiance. For the polariton-dot system in the antisymmetric state, the spontaneous emission rate is found to be zero. This phenomenon is related to subradiance in quantum optics. Numerical calculations are performed for spontaneous decay rate of an excited state in GaSb and GaAs.

References

[1] S. John, *Phys. Rev. Lett.* **58**, 2486 (1987); E. Yablonovitch, et al, *Phys. Rev. Lett.* **67**, 2295 (1991).
[2] V. I. Rupasov and M. Singh, *Phys, Lett. A* **222**, 258 (1996).